

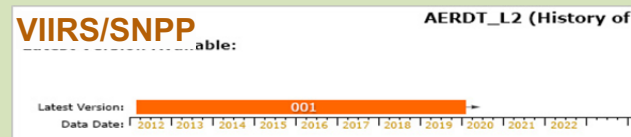
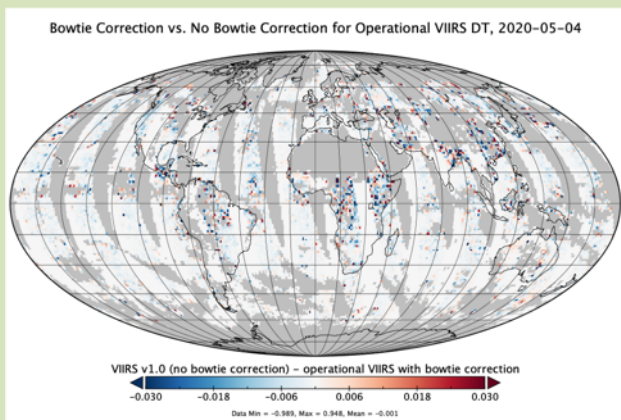
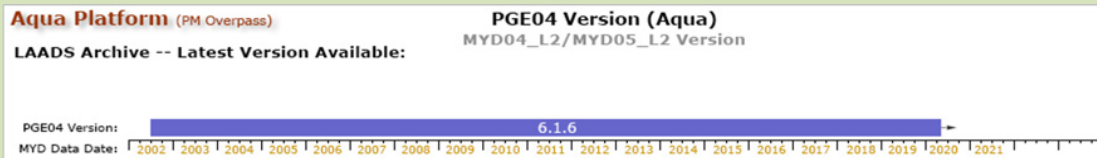
# Update on the Dark-Target aerosol retrieval project

R. Levy<sup>1</sup>, S. Mattoo<sup>2</sup>, V. Sawyer<sup>2</sup>, Y. Zhou<sup>3</sup>, Y. Shi<sup>3</sup>, M. Kim<sup>4</sup>, R. Kleidman<sup>2</sup>, P. Gupta<sup>5</sup>, Z. Zhang<sup>6</sup>, S. Gassó<sup>7</sup>, L. Remer<sup>8</sup>

<sup>1</sup>GSFC/613, <sup>2</sup>SSAI/613, <sup>3</sup>UMBC/613, <sup>4</sup>NPP/613, <sup>5</sup>USRA/MSFC, <sup>6</sup>ADNET/610, <sup>7</sup>ESSIC/613, <sup>8</sup>JCET/UMBC

- MODIS: C6.1 continuing with no known new issues
- VIIRS: Beta Version 1 in LAADS archive 5110

<https://atmosphere-imager.gsfc.nasa.gov/>

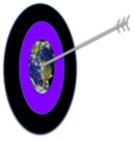


- VIIRS Version 1.1 (bow-tie restoral) in archive 5111
- NRT/Worldview: now use GFS “forecast” valid at t=T



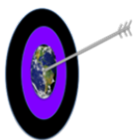
## Dark Target funding sources (how we cobble together for MODIS and VIIRS)

- Senior Review: Terra/Aqua algorithm maintenance (MODIS)
  - Ensures DT is running on MODIS (C061), fix bugs, MsWG calibration
  - Global view of aerosol 'trends'
  - Ensured 'Beta' version for VIIRS (001) would be available
  - Near Real Time (NRT)
  - No major new science or improvements
- MEaSUREs: (Making Earth Science Data Records for Use in Research Environments):  
Porting DT to Geostationary and creating merged GEO/LEO
  - **Creating 'The Package': modularizing the DT algorithm**
  - Revisit over-land surface reflectance assumptions/parameterization
  - GEO-LEO also now part of C. Hsu's project (DT/Deep Blue merge)
- Terra Aqua SNPP Science: Levy group lead or participation
  - Heavy aerosol retrieval (Smoke/Dust/Haze)
  - Non-spherical dust over ocean
  - Consistent aerosol models (join with UV observations, like VIIRS/OMPS)
  - Trends of aerosol and fires over India
- PACE: Unifying DT, DB and OMI aerosol retrieval algorithms for OCI.
- Etc: Participation in A-CCP, GOES-R project science, Goddard's IRAD and STG



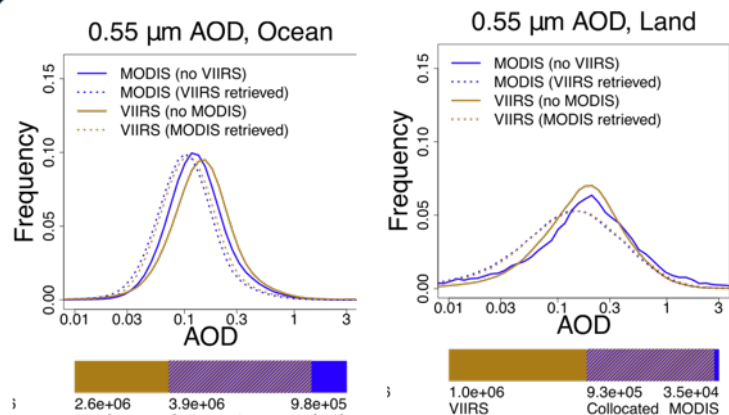
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# Papers since last STM

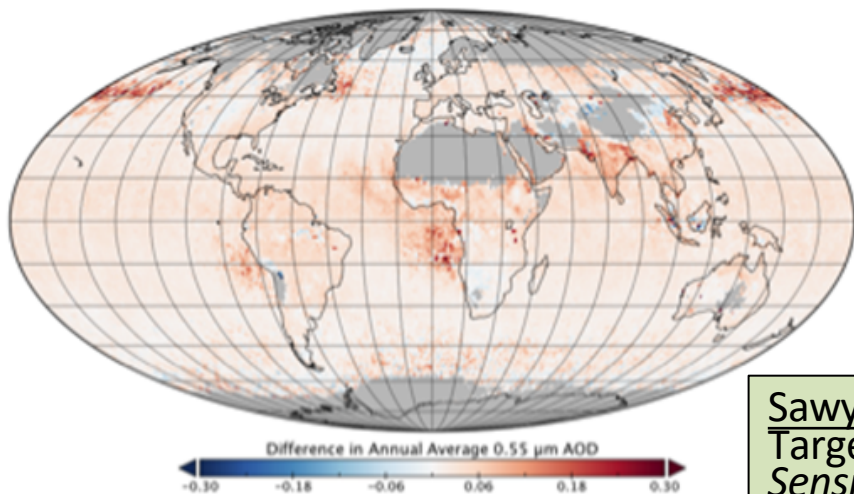


# Using VIIRS SNPP to continue MODIS for a Climate Data Record

Virginia Sawyer, Robert C. Levy, Shana Mattoo, Geoff Cureton, Yingxi Shi, Lorraine Remer



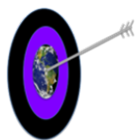
QA-Filtered Aerosol Optical Depth, VIIRS - MODIS, 2015



Version 001: Compared to MODIS Aqua DT:

- Values of aerosol optical depth (AOD) are highly correlated with MODIS Aqua, and nearly identical where both sensors retrieve on the same day
- VIIRS is offset higher than MODIS because of solo-sensor retrievals
- Solo-sensor retrievals skew higher than collocated retrievals for both MODIS and VIIRS, but by different amounts for each sensor, and also by different amounts over land vs. ocean
- Most solo-sensor retrievals come from VIIRS rather than MODIS, because wider swath and finer resolution = more retrieved area per day

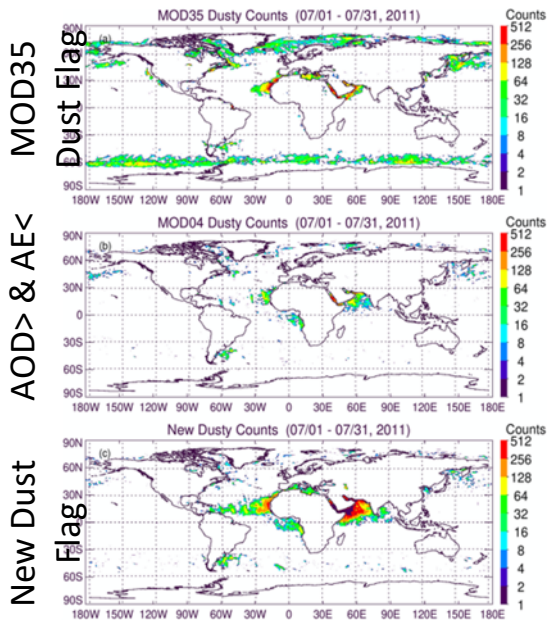
Sawyer, V., et al., 2020. "Continuing the MODIS Dark Target Aerosol Time Series with VIIRS." *Remote Sensing*, [[10.3390/rs12020308](https://doi.org/10.3390/rs12020308)]



# Dust detection and dust model for DT ocean algorithm

Yaping Zhou, Robert C. Levy, Shana Mattoo, Lorraine A. Remer, Yingxi Chen, Reed Espinosa, Chenxi Wang

## Dust detection:

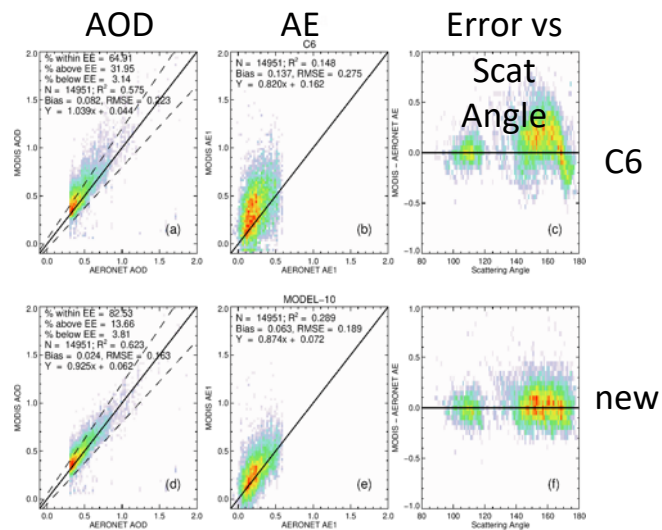


The DT algorithm for dust over ocean has long-standing biases due to assuming spheres, instead of non-spheres. Solution is:

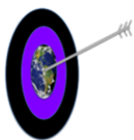
- Detect 'likely' dust using series of visible/NIR/IR tests.
- Apply non-spherical model (collection of spheriods)

Result is improved (AOD), fine mode fraction (FMF) and angstrom exponent (AE).

## Dust retrieval



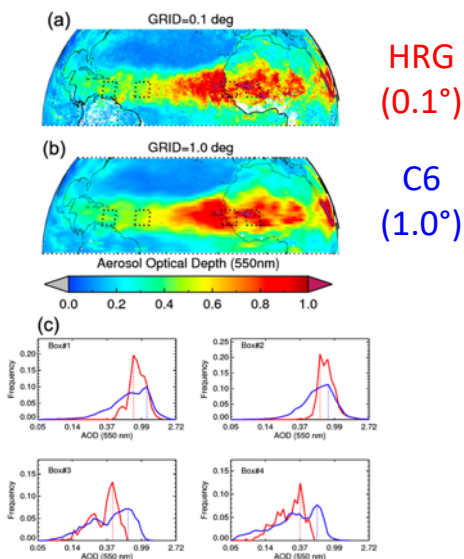
- Zhou, Y., et al. Dust Aerosol Retrieval over the Oceans with the MODIS/VIIRS Dark Target algorithm. Part I: Dust Detection (<http://dx.doi.org/10.1029/2020EA001221>)
- Zhou, Y. et al. Dust Aerosol Retrieval Over the Oceans with the MODIS/VIIRS Dark Target algorithm. Part II: Non-Spherical Dust Model (<http://dx.doi.org/10.1029/2020EA001222>).



# Towards integration of GEO and LEO

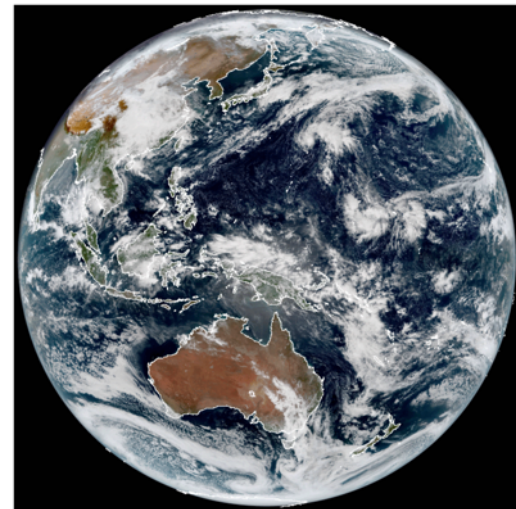
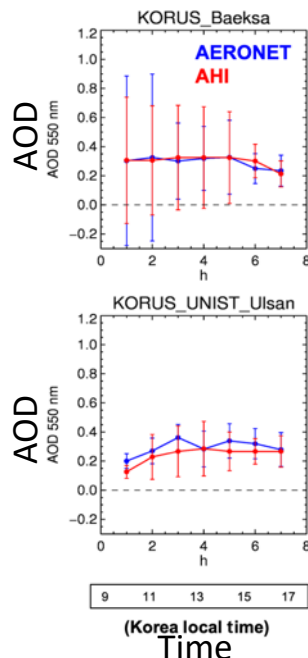
P. Gupta, R. Levy, S. Mattoo, S. Christopher, L. Remer, R. Holz, A. Heidinger, et al.

What resolution should we compare products?



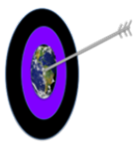
Monitor dust transport across the Atlantic Ocean during June 2018.

Using GEO to study diurnal cycle



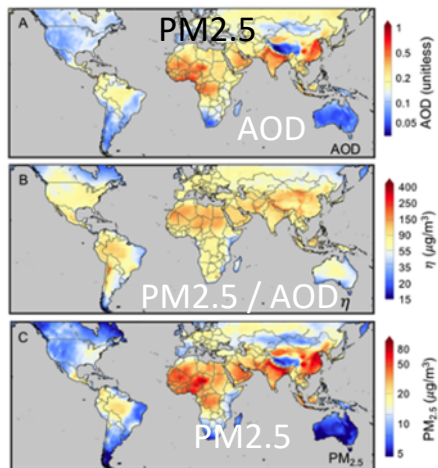
- Gupta, P., et al., 2020. "High-Resolution Gridded Level 3 Aerosol Optical Depth Data from MODIS." Remote Sensing, 12 (17): 2847 [10.3390/rs12172847]
- Gupta, P., et al. 2019. "Retrieval of aerosols over Asia from the Advanced Himawari Imager: Expansion of temporal coverage of the global Dark Target aerosol product." Atmos. Meas. Techniques, [10.5194/amt-12-6557-2019]





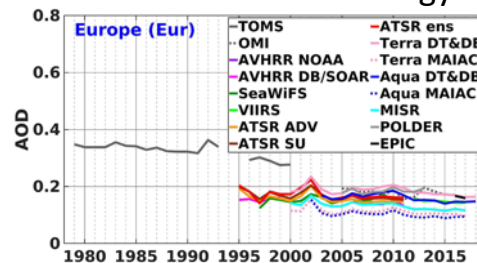
# Doing 'science' with the DT products

Using satellites +  
models to estimate

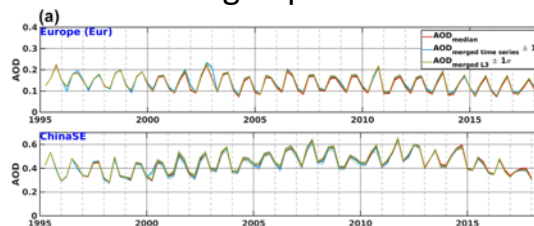


for 1998-2018

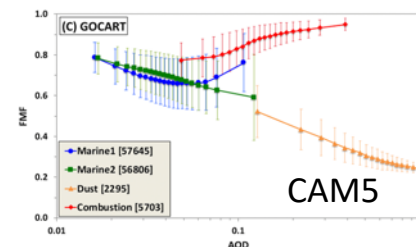
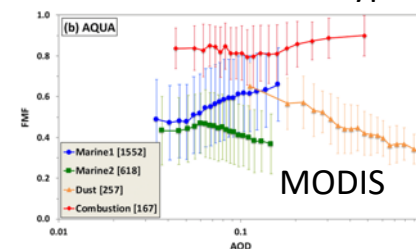
Using satellites +  
statistics for climatology



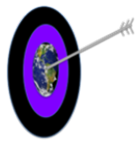
Merged products



FMF versus AOD to  
determine aerosol 'type'



- Hammer, M. S., et al., 2020. "Global Estimates and Long-Term Trends of Fine Particulate Matter Concentrations (1998–2018)." Environmental Science & Technology, [10.1021/acs.est.0c01764]
- Sogacheva, L., et al., 2020. "Merging regional and global aerosol optical depth records from major available satellite products." Atmos. Chem. Phys., [10.5194/acp-20-2031-2020]
- Yu, H., et al., 2020. "Interannual variability and trends of combustion aerosol and dust in major continental outflows revealed by MODIS retrievals and CAM5 simulations during 2003–2017." Atmos. Chem. Phys., [10.5194/acp-20-139-2020]



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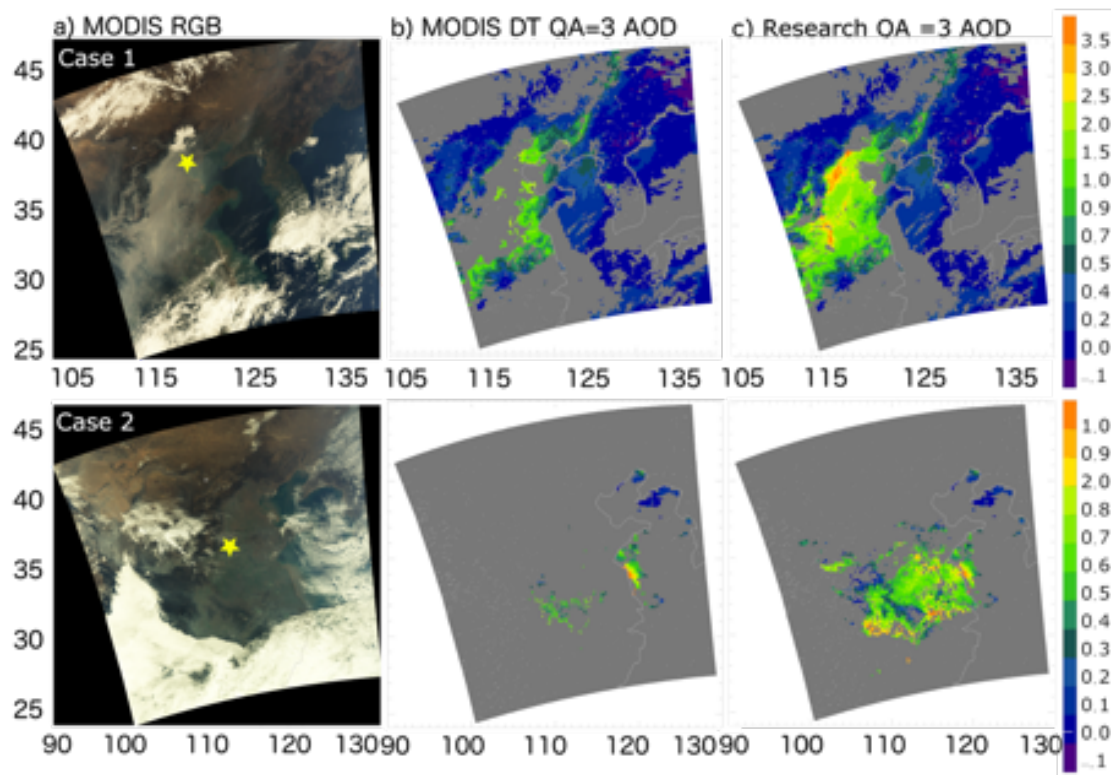
# In Progress since last STM





# A Dark Target research aerosol algorithm for MODIS observations over eastern China: Increasing coverage while maintaining accuracy at high aerosol loading

Yingxi R. Shi, Robert C. Levy, Leiku Yang, Lorraine A. Remer, Shana Mattoo, and Oleg Dubovik



DT algorithm fails over heavy haze, such as over Beijing and northeast China during Winter season

- Failure from 'inland water mask' and 'snow mask'
- AOD errors due to:
  - Beijing aerosol at  $H < 1\text{km}$  rather than assumed  $H = 2\text{km}$
  - $\text{SSA} \sim 0.95$  rather than assumed 0.9
- Develop 'research' algorithm that has improved masks and new aerosol optical model

Research product increases coverage and accuracy.



# An evaluation of the DT surface reflectance (MODIS, VIIRS and GEO)

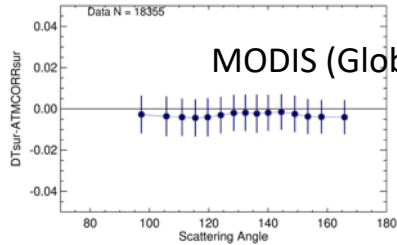
Mijin Kim, Robert C. Levy, Lorraine A. Remer, and Shana Mattoo

## Differences between DT surface reflectance and the atmospherically-corrected reflectance

Difference between DT-sur and ATMCORRsur with Scatt\_Angle

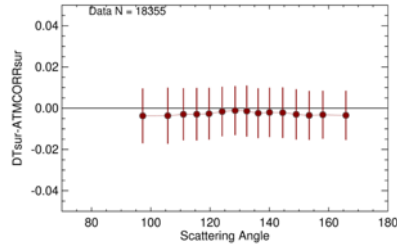
MYD04, Blue

MODIS (Global)



Difference between DT-sur and ATMCORRsur with Scatt\_Angle

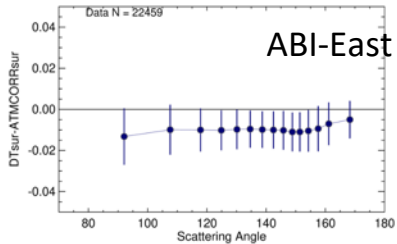
MYD04, Red



Difference between DT-sur and ATMCORRsur with Scatt\_Angle

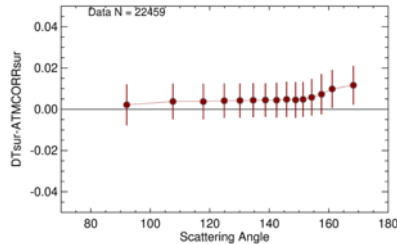
ABIE, Blue

ABI-East



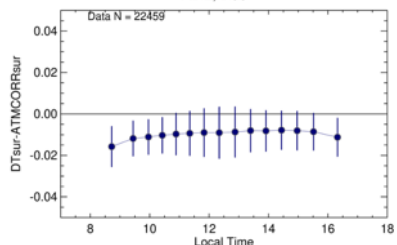
Difference between DT-sur and ATMCORRsur with Scatt\_Angle

ABIE, Red



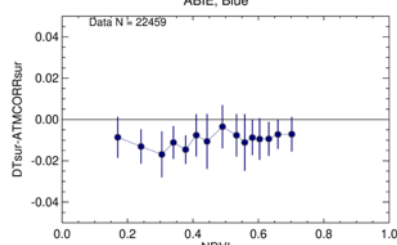
Difference between DT-sur and ATMCORRsur with LT

ABIE, Blue



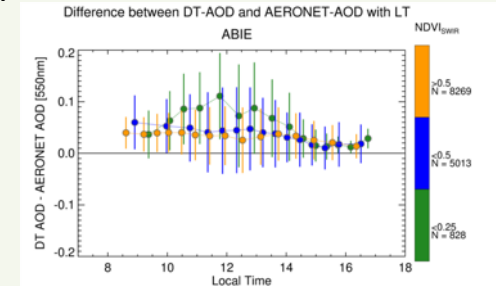
Difference between DT-sur and ATMCORRsur with NDVI

ABIE, Blue

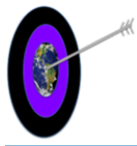


Identify the issues in the current surface reflectance parameterization process, and investigate the improvement of DT algorithm.

- ABIE DT product showed higher error in surface reflectance than the MODIS DT products, and revealed a change with scattering angle and  $NDVI_{SWIR}$  also.



- Underestimation in surface reflectance corresponds to the overestimation of AOD.
- Diurnal variations were found in both errors in surface reflectance and AOD.
- Accordingly, we are investigating a new SR parameterization.

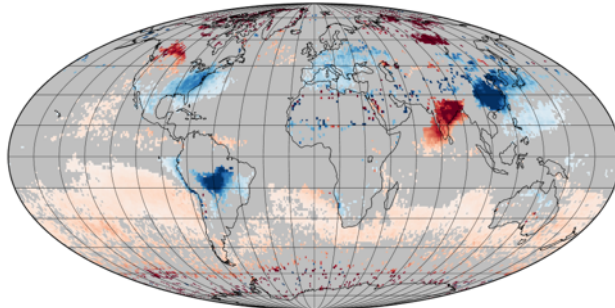


# Consistency of Trends from Terra and Aqua MODIS

V. Sawyer, R. Levy, S. Mattoo, et al.,

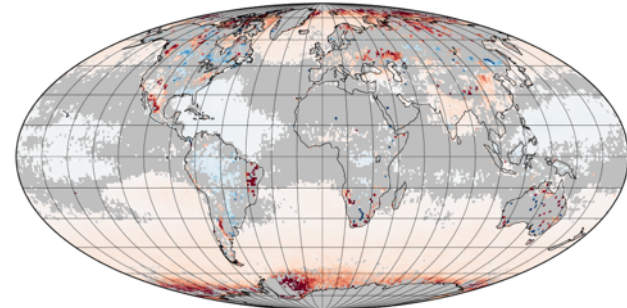
After all the updates and calibration and such, how consistent are 'Trends' from Terra and Aqua MODIS? (2002-2020)

Trend in 0.55  $\mu\text{m}$  AOD, Terra, June 2002 – June 2020



AOD change per year where  $p \leq 0.05$

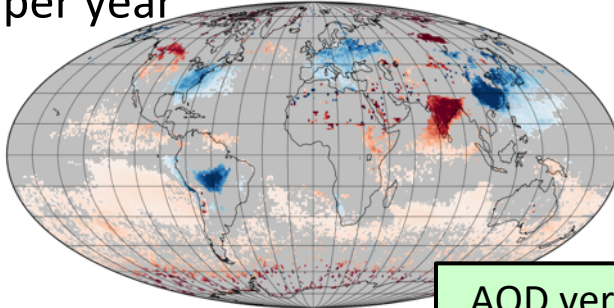
Fine Mode Fraction Trend, Terra, 2002–2020 ALL



Change in FMF per year where  $p \leq 0.05$

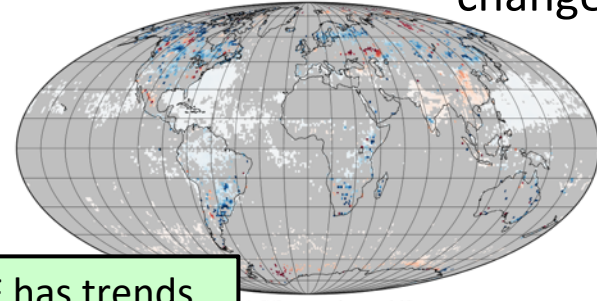
Terra

Trend in 0.55  $\mu\text{m}$  AOD, Aqua, June 2002 – June 2020



AOD change per year where  $p \leq 0.05$

Fine Mode Fraction Trend, Aqua, 2002–2020 ALL



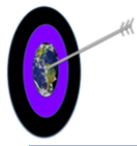
Change in FMF per year where  $p \leq 0.05$

Aqua

AOD very consistent but FMF has trends.  
Spectral calibration drift?

AOD  
change per year

FMF  
change per year

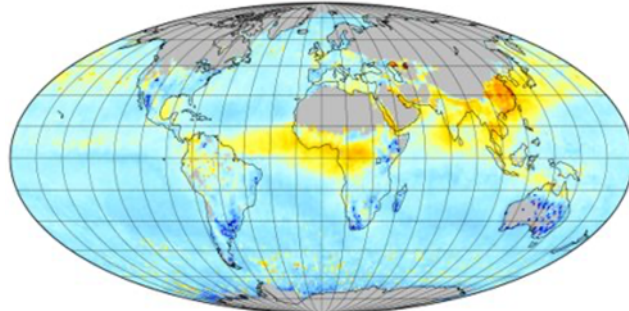


# “The Package”: Onwards toward C7

S. Mattoo, V. Sawyer, et al.

As we have ported DT from MODIS to VIIRS and other sensors, how do we ensure that MODIS code doesn't become obsolete? We also want DT code to be flexible

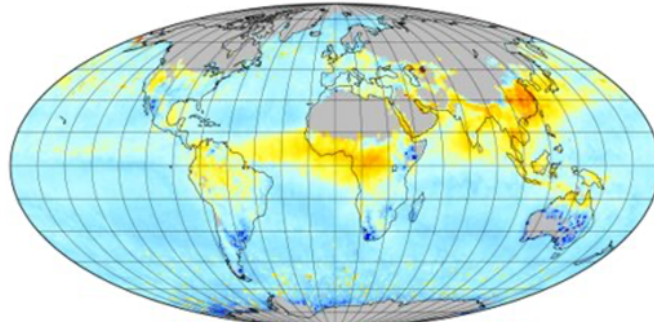
Total AOD, Aqua C6.1, March 2011



QA-Filtered AOD at 0.55  $\mu\text{m}$

0.01 0.10 1.00

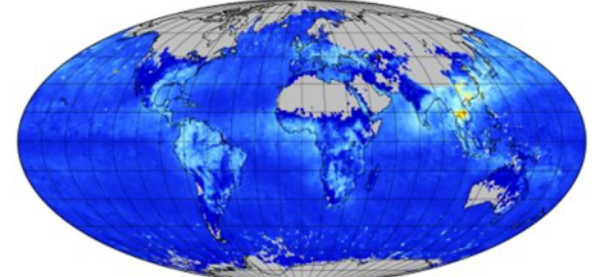
Total AOD, Aqua C7 Test, March 2011



QA-Filtered AOD at 0.55  $\mu\text{m}$

0.01 0.10 1.00

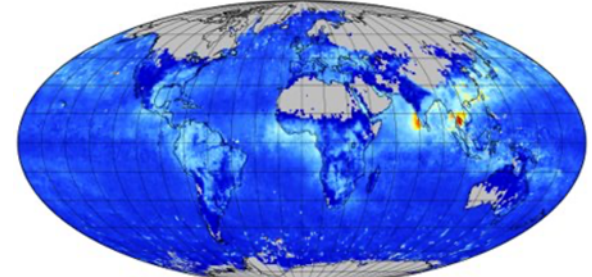
Fine Mode AOD at 0.55  $\mu\text{m}$ , Aqua C6.1, March 2011



Monthly Average Small AOD

0.00 0.20 0.40 0.60 0.80 1.00

Fine Mode AOD at 0.55  $\mu\text{m}$ , Aqua C7 Test, March 2011



Monthly Average Small AOD

0.00 0.20 0.40 0.60 0.80 1.00

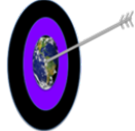
C6.1

“The Package”

AOD

Fine Mode AOD





# Near and Far Future

- **Finalize ‘the package’ (general modular code) that reports in NetCDF (S. Mattoo)**
- **Under Senior Review ‘maintenance’ we intend to:**
  - ❑ Continue validation (Y. Shi)
  - ❑ Continue looking at trends (V. Sawyer)
  - ❑ Finish adding dust-detection/non spherical dust over ocean (Y. Zhou)
  - ❑ Revisit our list of reported SDS’s (balance of information versus file size/confusion)
  - ❑ Add calculations for ‘true’ Fine Mode Fraction over land (re-do LUTs)
- **Dark Target “science” in discussion (ROSES?)**
  - ❑ Heavy aerosol retrieval over Beijing and other region (Y. Shi)
  - ❑ Revisit surface reflectance assumptions (M. Kim)
  - ❑ Revisit spatial variability structure for cloud/surface masking (R. Kleidman)
  - ❑ Include uncertainties (Jacobians, ensemble, error propagation, etc. )
  - ❑ Machine learning exercises? Cloud/smoke detection/masking?
- **Collaborative science (leveraging other work)**
  - ❑ Integrate with GEO imagers (my MEaSURES project, with P. Gupta, Jennifer Wei, )
  - ❑ Integrate with Deep Blue (new GEO funding with C. Hsu)
  - ❑ Joint UV-VIS/NIR retrieval (e.g. OMPS + VIIRS, led by S. Gassó)
  - ❑ Unified UV-VIS-NIR-SWIR retrieval (e.g OCI on PACE, led by L. Remer)